GEOPHYSICAL SURVEYS FOR GROUND WATER EVALUATION NEAR WAIKOLOA, SOUTH KOHALA, HAWAII

LALAMILO II WELL SITES

GEOPHYSICAL SURVEYS
FOR
GROUND WATER EVALUATION
NEAR WAIKOLOA, SOUTH KOHALA, HAWAII

Prepared For:

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(Our Project #90004)

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1.0 INTRODUCTION

This report contains the results of a geophysical survey to assist the evaluation of fresh water resources near Waikoloa, South Kohala, on the Island of Hawaii. The work was performed for Mauna Lani Resort (MLR) between January 19 and January 23, 1990.

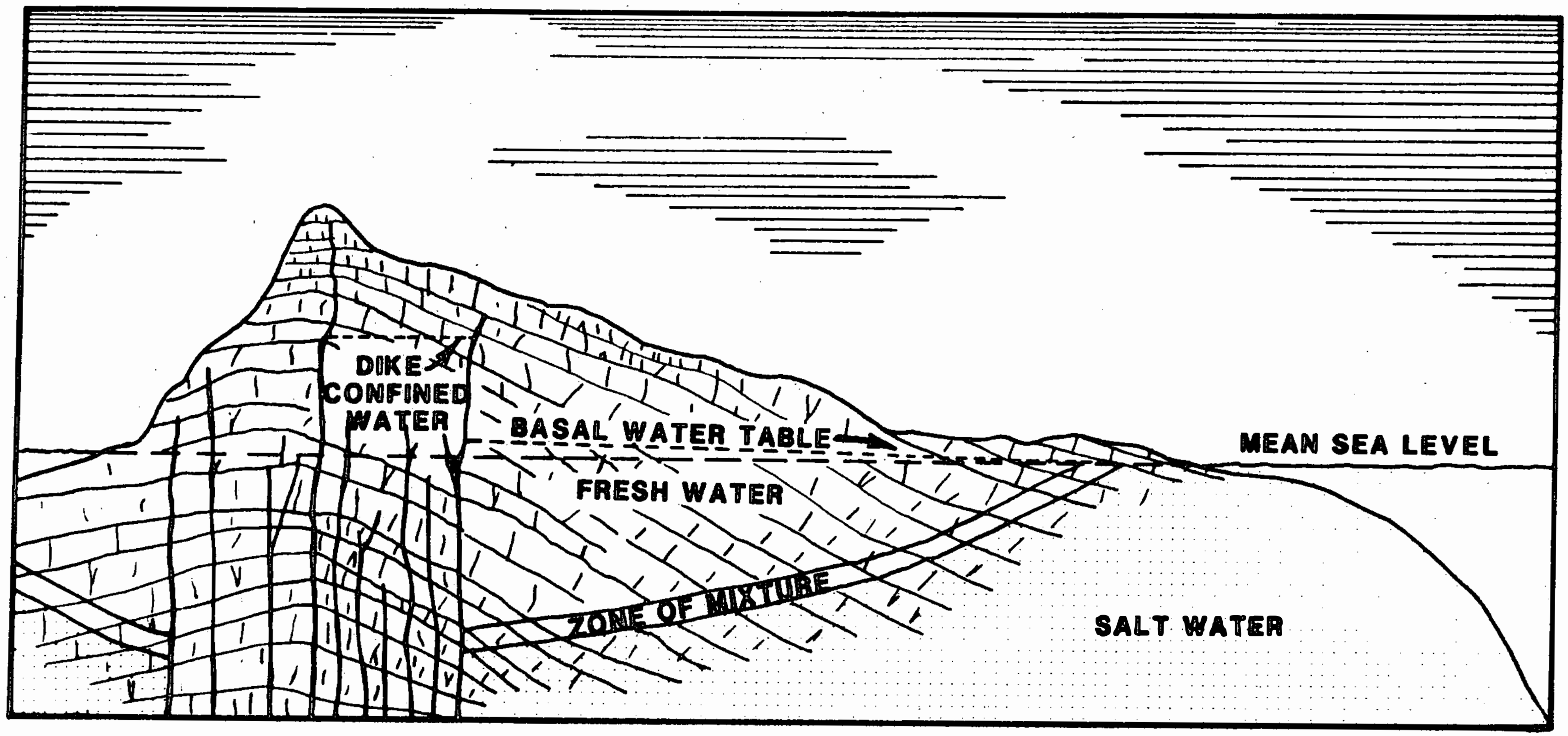
The objectives for the geophysical survey can be understood from the hydrogeologic cross-section, typical of a volcanic island, shown in Figure 1-1. The volcanic rocks are generally highly permeable and rainfall rapidly infiltrates into the ground and migrates downward to the water table, and eventually discharges into the ocean. Fresh water in these settings is found in two environments.

1. Dike confined waters. Above the rift zone intrusive dikes originating from a magma source below can form ground water dams, and behind these natural dams significant quantities of ground water can be stored.

2. Basal fresh water. The high permeability of the volcanic rocks allows sea water to enter freely under the island, and a delicate balance is reached where a lens of fresh water floats on sea water. The Ghyben-Herzberg relation states that for every foot of fresh water head above sea level there will be 40 ft of fresh water below sea level.

The basal water resource was the focus in the investigations for MLR. The drilling depth to the basal fresh water lens rapidly increases with elevation, and the objective of geophysical surveys is to determine the drilling depth to fresh water and the thickness of the fresh water lens. The impetus for using geophysics is that the cost of a geophysical station is about one-five-hundredth of the cost of drilling a well at elevations above 1,000 ft. Geophysical surveys, combined with other hydrogeologic information, are used to provide optimum locations for well placement and well completion depths.

The geophysical method employed was time domain electromagnetic (TDEM) soundings. This method was selected because it has proven effective in prior surveys in similar settings in Hawaii.



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SCHEMATIC HYDRO-GEOLOGIC
CROSS SECTION
Mauna Lani Resort

PROJECT NO.: 90004 FIGURE 1-1

2.0 LOGISTICS AND DATA ACQUISITION

A brief description of the fundamentals of TDEM is given in Appendix A. Briefly, the logistics of a TDEM measurement consist of:

1. Laying out a square loop of insulated wire. A generator placed in the loop is used to drive current pulses through this closed loop. The dimensions of the square loops employed depend on the exploration depth requirements. The dimensions of the loops used for MLR were 1,000 ft by 1,000 ft on each side.

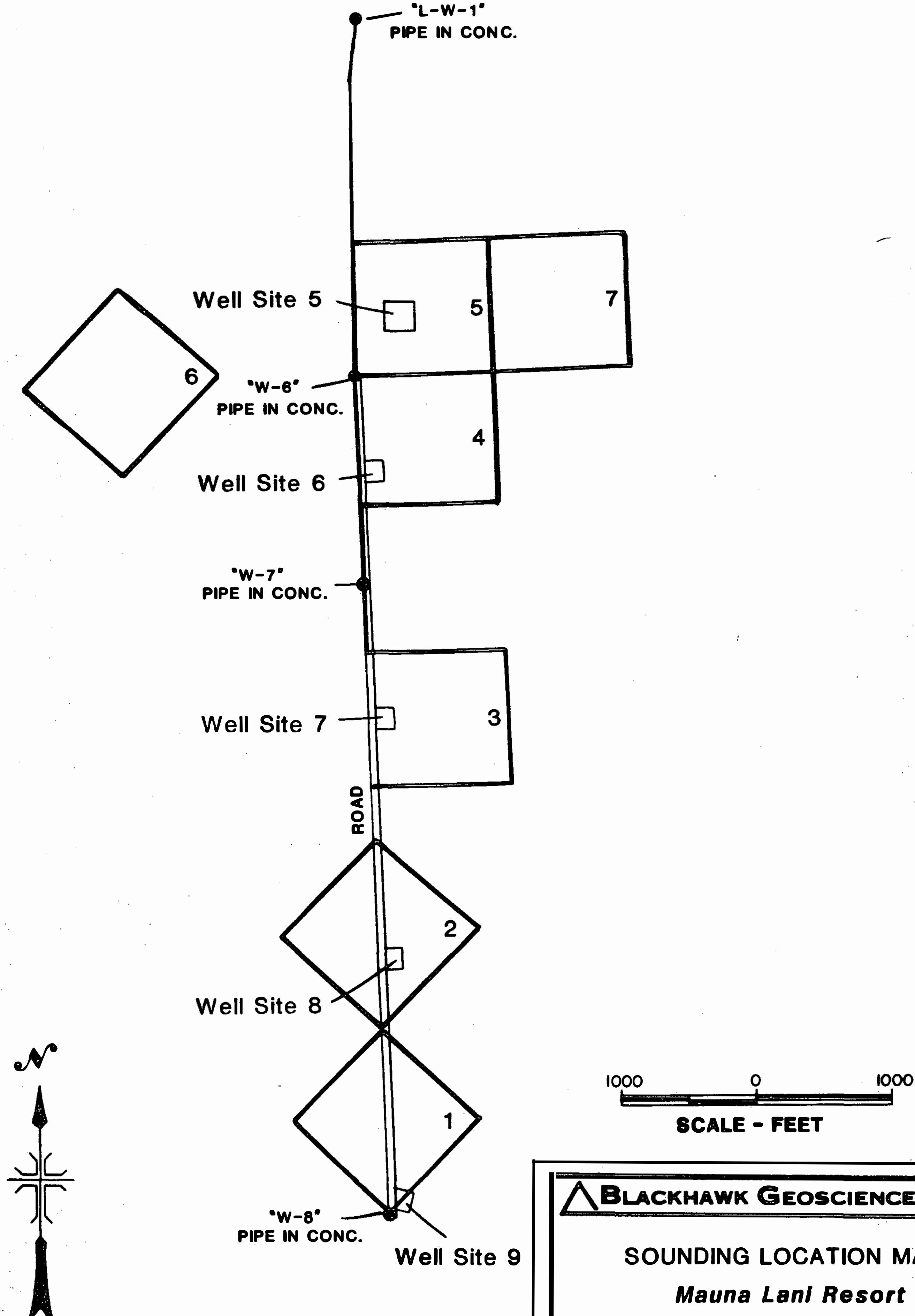
   Where possible, transmitter loop wires were positioned with at least one wire near roads and trails. Loops 6 and 7 required off road placement using a four wheel drive vehicle for transport of equipment.

2. Making a measurement with a receiver in the center of the loop. The data acquired at each station was stored in the field on a solid state data logger and subsequently dumped to a computer at the end of each field day. The data acquired at each station usually consisted of measurements at several receiver gain settings and transmitter frequencies in order to assure data quality and to obtain data over the largest time range possible. Data quality was generally very good, except in the soundings adjacent to a high tension power line (soundings 4 and 5).

During three days of field work 7 stations (soundings) were completed. A daily log of field activity is given in Table 2-1. A north-south trending dirt road provided access to the sites. Figures 2-1 and 2-2 show the location of the soundings conducted for MLR.

Table 2-1. Daily log of field activities

Date (1990)	Activity
January 18	Meeting with MLR personnel.
January 19	Measurement soundings 1, 2 and 3.
January 20	Measurement of soundings 4 and 5.
January 23	Measurement of soundings 6 and 7.
January 26-27	Demobilize from Kailua-Kona, HI to Golden, CO.



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SOUNDING LOCATION MAP

Mauna Lani Resort

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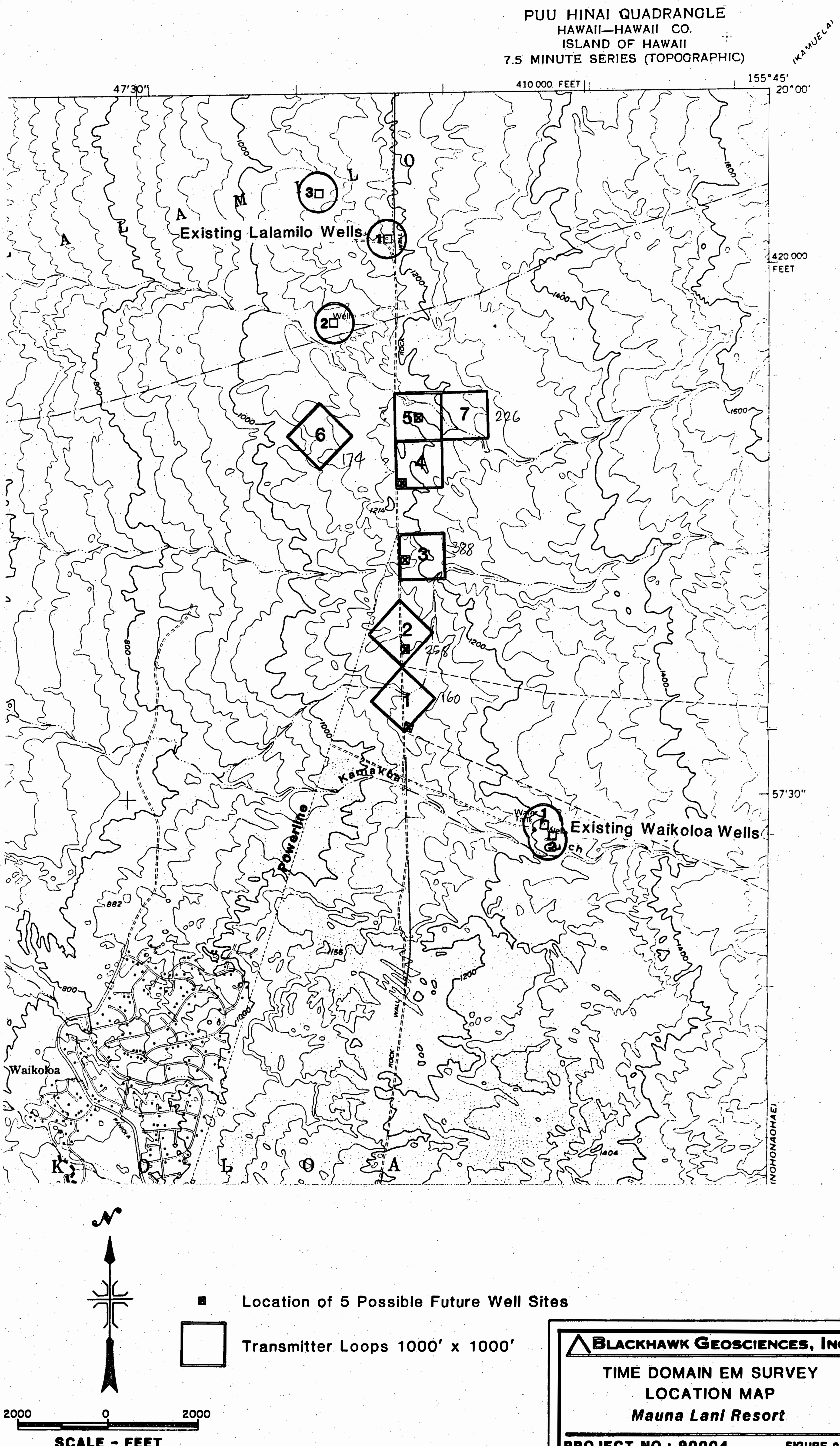
FIGURE 2-1



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TIME DOMAIN EM SURVEY
LOCATION MAP
Mauna Lani Resort

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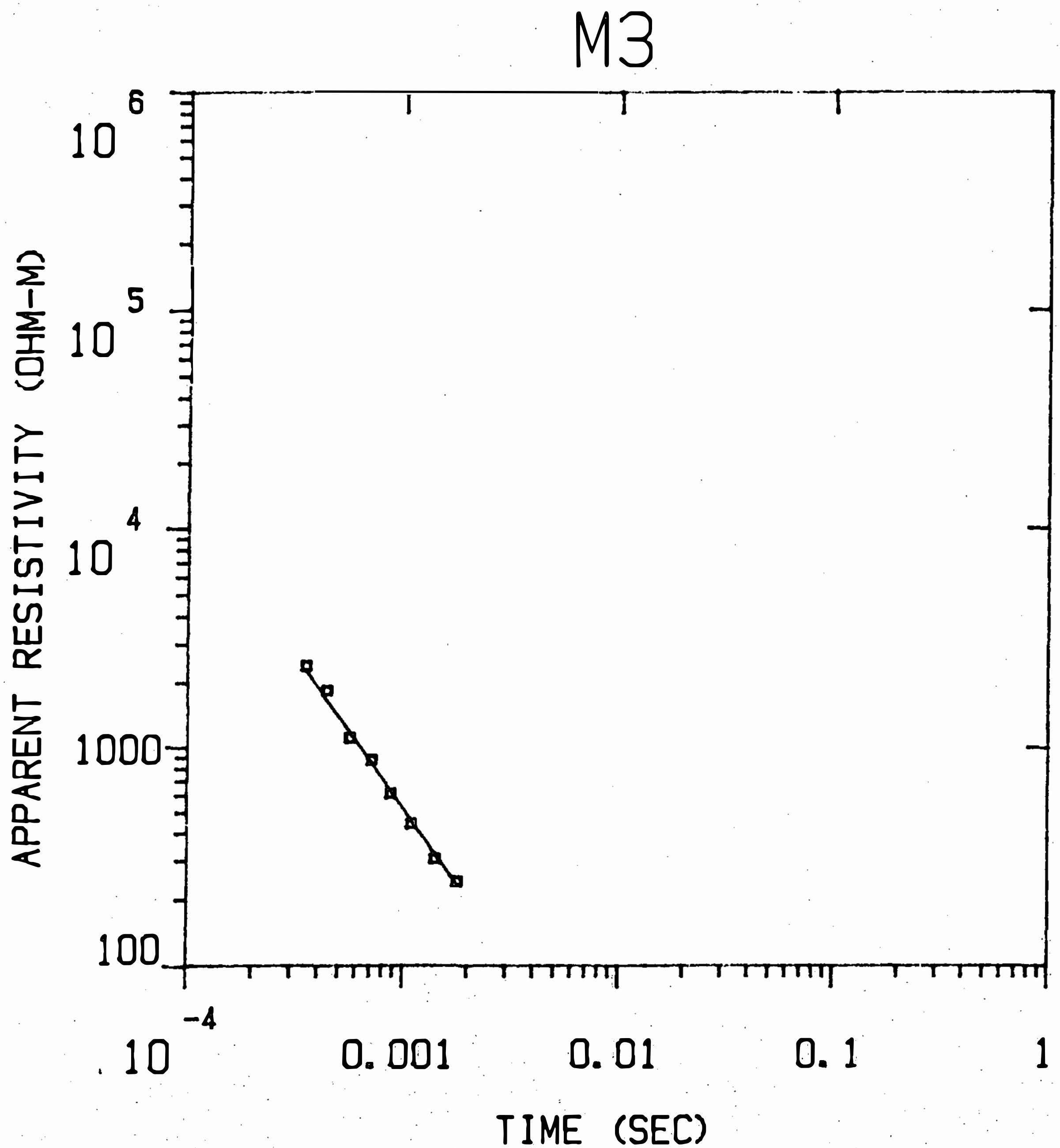
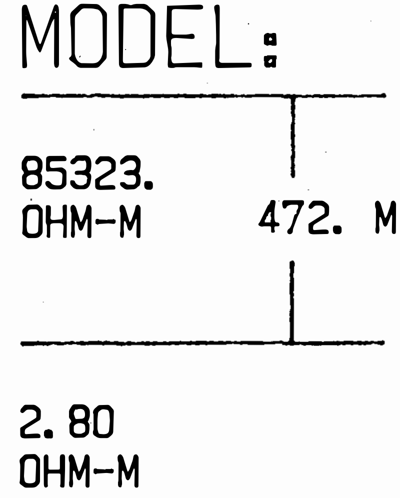
3.0 DATA PROCESSING

The objective of data processing is to derive from the TDEM measurements in the center of the loop the resistivity layering in the earth. The procedures of data processing are discussed in Appendix A. The results from data processing for each station are contained in Appendix B. A typical data set is given in Figures 3-1 and 3-2 for the station near the proposed well site 7 (loop 3). Figure 3-1 shows the measured data points (in terms of apparent resistivity) superimposed on a solid line. The solid line represents the computed behavior of the true resistivity layering shown on the right. Figure 3-2 lists in column 4 the error between measured and computed data in each time gate.

Figure 3-1 also shows that the resistivity layering in the upper 1,600 ft consists of two layers, - the first layer has a thickness of 472 m (1,548 ft) with a resistivity of greater than 1,000 ohm-m, and the second layer has a resistivity of 2.8 ohm-m. At all stations the data was interpreted with a two layer model.





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SOUNDING NEAR

PROPOSED WELL SITE 7

Mauna Lani Resort

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% ERROR: 8.84
CALIBRATION: 1
OFFSET: 152. M
RAMP: 200.0
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MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		353.6	1160.0		
85323.23	471.9	-118.4	-388.4	0.0	0.0
2.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	3.55E-04	2.39E+03	2.29E+03	4.499	
2	4.43E-04	1.84E+03	1.67E+03	10.559	
3	5.64E-04	1.11E+03	1.18E+03	-6.238	
4	7.13E-04	8.77E+02	8.51E+02	3.039	
5	8.81E-04	6.11E+02	6.31E+02	-3.271	
6	1.10E-03	4.41E+02	4.61E+02	-4.454	
7	1.41E-03	3.04E+02	3.23E+02	-5.806	
8	1.80E-03	2.40E+02	2.30E+02	4.225	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 8 DATA POINTS, RAMP: 200.0 MICROSEC, DATA: M3
1901 003N 003N Z OPR XTL H 5 8+100
Ch.21 = 0.2 Ch.22 = 0.089 Ch.23 = 19.5 Ch.24 =
RMS LOG ERROR: 3.68E-02, ANTILOG YIELDS 8.8433 %
LATE TIME PARAMETERS

* Blackhawk Geosciences *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.99		
F 2	0.00	0.00	
T 1	0.00	0.00	1.00
	P 1	F 2	T 1

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EXAMPLE INTERPRETATION SHEET

Mauna Lani Resort

PROJECT NO.: 90004 **FIGURE 3-2**

4.0 INTERPRETATION RESULTS

4.1 GENERAL

The objective of MLR and its ground water consultants is not to obtain the resistivity layering of the subsurface, but to infer from the resistivity information about the depth to salt water and the thickness of the basal fresh water lens. The translation of resistivity layering into hydrogeologic information is generally accomplished in two ways:

1. Using available knowledge about the relation between resistivity values and hydrogeology. For example, in the volcanic rocks of Hawaii rocks saturated with salt water will have resistivities less than 5 ohm-m. On the other hand, dry volcanic rocks can have very high resistivities (greater than 1,000 ohm-m).

2. Calibrating the geophysical interpretation at a well. A TDEM sounding was made near a well during a survey in December 1988 in the Waikoloa area, and this data was used for calibration in the present survey for MLR. The main parameter that can be adjusted in interpretation is the low resistivity of salt water saturated formations. In the sounding near the well at Waikoloa use of a resistivity value of 2.8 ohm-m resulted in good agreement between TDEM interpretations and water well data. Based on that calibration the resistivity value of the basal saline water was fixed in the interpretations of the soundings at MLR at 2.8 ohm-m.

4.2 CHARACTERISTICS OF GEOELECTRIC SECTION NEAR WAIKOLOA

The normal hydrogeologic section near Waikoloa consists of a three-layer section, i.e., an upper unsaturated volcanic zone, a fresh water saturated volcanic zone, and a saline saturated volcanic zone. The transition zone between fresh and saline saturated volcanics can probably be neglected in most cases due to its relatively small thickness compared to the other layers.

From the resistivity layering a measured hydrogeologic section was inferred. The interpretation scheme used for relating resistivity units to hydrogeologic information is shown in Table 4-1.

Table 4-1. Geoelectric layers and corresponding hydrogeologic units

Geoelectric Unit	Hydrogeologic Unit
Highly resistive (100 to 6,000 ohm-m)	Unsaturated volcanics Fresh/Brackish water saturated volcanics
Highly conductive (2 to 10 ohm-m)	Transition zone Saline saturated volcanics

Generally, it is difficult to discriminate between fresh water and slightly brackish water (less than 1,000 ppm chloride) saturated volcanics. The reason is that in addition to salinity, changes in porosity and lithology also influence formation resistivity, particularly at low values of chloride concentration.

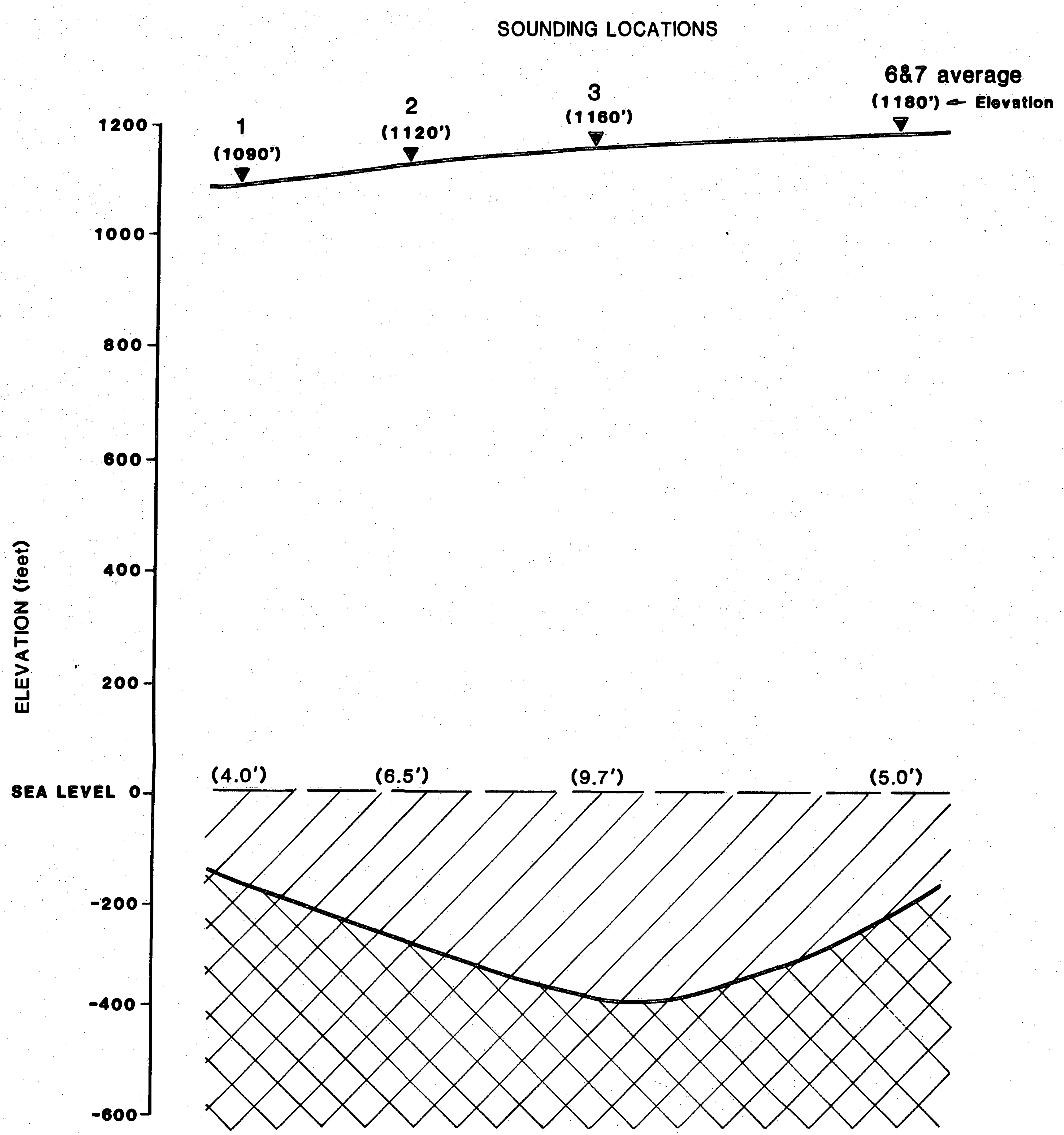
Figure 4-1 shows a cross section of the results of MLR's TDEM soundings. Soundings 4 and 5 are eliminated from the interpretation due to power line interference in the measurements. The cross section combines soundings 6 and 7 measured away from the power line with average values for elevation and all other interpreted parameters. The section shows the thickest fresh/brackish lens to be near proposed well site 7 (sounding 3). The thickness of the lens at this location is calculated to be 398 ft. Figure 2-1 shows the position of the soundings in relation to the proposed new wells.

The results are summarized below in Table 4-2.

Table 4-2. Hydrogeologic information derived from TDEM soundings

Sounding #	Surface Elevation (ft)	Elevation of Conductive Layer	Head of Fresh/ Brackish Water above Sea Level (water table) (ft)	Thickness of Fresh/ Brackish Water Lens (ft)
1	1090	-160	4	164
2	1120	-258	6.5	265
3	1160	-388	9.7	398
4*	1200	?	-	-
5*	1200	?	-	-
6	1140	-174	4.4	178
7	1220	-226	5.6	332

*Unreliable data due to influence of power line.



LEGEND

Salt Water

Fresh Water

(16.2') Calculated Elevation of Top of Fresh Water

(1250') Elevation of TDEM Measurement

VERTICAL EXAGGERATION 5 TO 1

1000 0 1000

SCALE - FEET

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HYDROGEOLOGIC CROSS SECTION
FROM TDEM INTERPRETATIONS

Mauna Lani Resort

PROJECT NO.: 90004 **FIGURE 4-1**

5.0 CONCLUSIONS

The TDEM survey indicates that in the area of proposed wells 6, 7, 8 and 9 the optimum well location is at sounding 3 near well location 7. At this location the head of fresh/brackish water is expected to be greater than 9.5 ft.

Power lines caused deterioration in data quality for soundings 4 and 5. Soundings 6 and 7 were measured away from the power line and combined for an average measurement along the cross section.